
MANAGING AGRICULTURAL RESIDUES

Edited by '

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Residue Management — What Does the Future Hold?

Paul W. Unger

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I. INTRODUCTION

Agricultural residues, mainly the stems, leaves, chaff, and husks that remain in fields after crops are harvested for their grain, seed, fiber, or other higher-value products, are currently receiving much emphasis for their soil erosion-control benefits. This is especially true when they are retained on or near the soil surface by using conservation tillage methods. Conservation tillage systems for which crop residues are retained on the soil surface reduce soil erosion,

runoff of surface water, summertime soil temperatures, number of trips across fields, and machinery costs; enhance water retention; and, at the same time, increase net returns to the farmer.¹

Some crop residues also are becoming increasingly important as sources of feed for animals and of fuel for energy production, heating, and cooking purposes. Crop residues often are of greater economic importance to producers than grain products in many developing countries.²

Competition for crop residues will continue to increase among the various users. This will result from the increasing emphasis on erosion control and environmental preservation as well as the ever-increasing world population and its concurrent increased need for fuel and feed products. Contributing to the emphasis on residue utilization for various purposes, thus on competition for residues, is the realization by producers that residues usually represent more than one half of the crop materials produced on a dry-weight basis. Cost of residue production in terms of labor, fuel, fertilizer, and machinery inputs is unavoidable. However, because of these production costs, it is not surprising that an increasing number of producers are seeking ways to obtain increased economic benefits from crop residues.

II. CONSERVATION TILLAGE

Conservation tillage is an umbrella term covering various types of tillage designed to retain crop residues on the soil surface. A commonly used definition of conservation tillage is any tillage system that results in at least 30% of the soil surface covered with residues after a crop is planted where soil erosion by water is dominant and residues equivalent to at least 1.1 Mg/ha of small-grain residues where soil erosion by wind is dominant.³ These amounts are general guidelines, and improvements in erosion-control technology are indicating that greater amounts are needed on some soils and lesser amounts on other soils to provide adequate protection against erosion.⁴

Fryrear and Bilbro⁵ discussed the value of surface residues for controlling wind erosion, and Alberts and Neibling⁶ discussed their value for controlling water erosion. In general, both types of erosion can be controlled effectively where sufficient residues are available and maintained on the surface. On highly erosive soils, where residue amounts are limited, and where available residues have limited effectiveness for controlling erosion, supplemental erosion control measures may be needed.

Tillage practices that involve management of crop residues on the soil surface are not new, but the term "conservation tillage" has only been used to describe these practices for the last 20 to 30 years. Various types of conservation tillage systems have been developed, with the extreme form being no-tillage (also called zero tillage or direct drilling). With no-tillage, all previous-crop residues are retained on the soil surface, with seeding of the next crop accomplished by opening a narrow slit in the soil for seed placement. In general, conservation tillage is better suited for crop production on well-drained soils than on poorly drained soils, in warm or temperate regions than in cool regions, and where crops are grown in rotation rather than where they are grown continuously.⁷ Some types of conservation tillage are relatively new, and much research is being conducted on the subject. Thus, improvements in conservation tillage technology are expected, especially with respect to making them more adaptable to a wider range of soils, climates, crops, and production systems such as crop/livestock systems.

A major advantage of maintaining crop residues on the soil surface, especially in subhumid and semiarid regions, is improved soil water conservation. This is a result of reduced runoff of surface water and improved soil surface conditions that allow more time for and permit greater water infiltration. Crop residues also reduce evaporation, which reduces the loss of stored soil water. Improved water conservation with conservation tillage is also important in humid regions where short-term droughts can severely limit crop yields on soils that have low water-holding capacities.

Steiner⁸ discussed residue effects on water conservation, and Horton et al.⁹ discussed residue effects on the surface energy balance, which affects soil-water relations as well as other energy-driven factors. Crop residue effects on soil physical conditions, which affect water conservation and other factors related to soil conservation and crop production, have been discussed by Kladingko.¹⁰

In general, conservation tillage systems that retain residues on or near the soil surface maintain soil organic matter contents at higher levels than clean tillage systems. As soil organic matter levels increase, soil physical factors such as aggregate stability, bulk density, and porosity and soil water factors such as infiltration, conductivity, and retention are positively influenced. Thus, soil physical conditions usually improve with time after initiation of a conservation tillage system.

Increases in residues on or near the soil surface and of soil organic matter due to implementation of conservation tillage systems also have a positive effect on the abundance and activity of soil micro- and macroorganisms.¹¹ Residues provide food for the organisms, which through their activity in soil help convert residues and organic matter into stable materials that are beneficial for improving soil physical conditions. Soil conditions usually improve with time due to increased biological activity where conservation tillage systems are used.

Continued improvements in water conservation, surface energy relations, and soil physical conditions should occur as improved techniques for retaining and managing surface residues are developed. However, dryland (nonirrigated) crops often do not produce enough residues to adequately reduce runoff or suppress soil water evaporation in subhumid and semiarid regions. In such regions, development of practices that retard the rates of residue decomposition would be especially beneficial with regard to water conservation.

Conservation tillage systems, based on managing crop residues on the surface, are virtually the exact opposite of clean tillage systems, which are based on residue destruction or incorporation into soils. Clean tillage was (and in many cases, still is) practiced to achieve better weed, insect, and plant disease control than that deemed possible with conservation tillage. Thus, when conservation tillage systems were introduced, there were valid reasons for concern because surface residues interfere with weed control operations involving tillage or herbicide applications, serve as protection for insects, and harbor disease organisms.

Indeed, weed, insect, and disease problems are greater with conservation tillage than with clean tillage under some conditions and for some organisms.¹²⁻¹⁴ However, there also are many cases where fewer problems occur with conservation tillage. Conservation tillage systems require greater management inputs than clean tillage systems. Also, producers should be aware that the potential for problems such as weeds, insects, or plant diseases exists. Thus, they should regularly examine their fields and crops for signs of impending problems and take immediate corrective action. Some types of problems can be circumvented by using crop rotations, planting crop varieties or species that resist or tolerate the problem, and using tillage rotations. Use of appropriate chemicals (herbicides, insecticides, fungicides, etc.) may provide adequate protection to save a growing crop. All the above could possibly be combined into an integrated pest management program that could further reduce the potential for serious pest problems. In general, continued progress in pest control techniques should minimize the potential for the development of serious weed, insect, and plant disease problems in conservation tillage systems.

Other early concerns involving maintenance of crop residues on or near the soil surface in conservation tillage systems involved plant nutrient applications, utilization of nutrients by plants, and nutrient cycling in the crop production system,¹⁵ as well as the phytotoxicity of crop residues on succeeding crops.¹⁶ Where reduced tillage rather than no-tillage crop production is practiced, surface-applied plant nutrients (fertilizers) usually are adequately incorporated into soil so that utilization by plants is not adversely affected. With no-tillage, surface-applied fertilizers such as soluble nitrogen materials readily move into the soil when water is applied. In contrast, slowly soluble fertilizers — for example, phosphorus — remain at the surface.

However, because of generally wetter soil conditions at the surface with no-tillage, phosphorus uptake usually remains adequate for good plant development and yield.

Prolonged use of no-tillage affects both plant nutrient distribution and soil pH with soil depth.¹⁵ Because of nutrient uptake by plant roots and deposition of those nutrients at the surface when residues decay, nutrients such as slowly soluble phosphorus accumulate at the surface. Also, soil pH usually decreases with continued use of no-tillage, especially where soil-acidifying fertilizers (generally, nitrogen materials) are used.

Phosphorus accumulation at the surface usually is not a serious problem, but low soil pH seriously hampers growth and yield of some crops. Lime (calcium carbonate) is usually applied to correct the low pH problem. However, surface-applied, slowly soluble lime tends to remain at the surface, resulting in no change in subsurface soil pH and, thus, failing to reverse the adverse affects on growth and yield of some crops. This problem can be overcome by periodic incorporation of adequate lime by tillage or use of injection-type equipment to place the lime at the desirable depth in the soil. The latter can be accomplished in a reduced-tillage system without greatly impacting the amount of crop residues retained on the soil surface. Also, because reduced- and no-tillage soils usually are wetter near the surface than clean tillage soils, more of the slowly soluble lime may move to greater depths than where clean tillage is used. Improved techniques are needed to overcome this soil pH problem where no-tillage crop production systems are used.

The phytotoxic influence of some plant residues on subsequent crops has been recognized for centuries.¹⁶ This influence can be beneficial — for example, to reduce weed problems — or detrimental to subsequent crops. Although considerable evidence shows that certain plant species interfere with other species through the toxic influence of their residues, a better understanding of which plants release toxic substances that subsequently inhibit subsequent crops is needed. Such information would be especially beneficial where residues are maintained on the surface in conservation tillage systems. For such systems, the information would indicate which crops could be safely grown in succession and how the residues could be managed most effectively. Activated charcoal might be used to quickly remove toxins from small areas. Inoculation with organisms that efficiently metabolize toxic compounds might be a way of reducing the phytotoxic influence on crops.¹⁶

Economics is probably the factor that most often determines whether a given practice or crop production system will be adopted by producers. Many factors influence crop production economics with regard to inputs, outputs, and returns to the production enterprise. Harman¹⁷ reviewed the economics of conservation tillage systems in detail. Although there are exceptions, conservation tillage usually was as economical as, and possibly even more economical than, clean tillage, especially when the benefits of lower equipment needs with conservation tillage were included in the analyses.

Economic advantages of conservation tillage systems apply not only to producers, but to society as a whole through an improved environment. A major advantage of reduced erosion is the reduction in the amount of sediment deposited off site (on roads, in ditches, in waterways, in lakes, in buildings, etc.) with the subsequent reduction in cost of removing the sediment and of repairing the damages. Reduced erosion also results in cleaner water and air, which also have indirect economic benefits to the nonfarm segment of society through an improved environment.

Use of conservation tillage systems may be less desirable than use of clean tillage systems with regard to the environment because conservation tillage relies more heavily on chemicals for pest control.¹⁸ This increases the potential of some chemicals to enter surface or subsurface water supplies. However, many factors, such as pesticide chemistry, timing and intensity of water application, heterogeneity of soil properties, and other site-specific conditions, influence chemical movement. Therefore, it is not possible to predict whether conservation tillage will

ultimately cause increased groundwater contamination. Undoubtedly, pesticides in the future will be more effective as well as safer when applied at proper rates. Also, improved equipment, such as green-vegetation-sensing sprayers that spot apply herbicides only to growing weeds rather than to the entire field, hooded sprayers that reduce herbicide drift, and directed sprayers that apply herbicides only to targeted plants, will further reduce the potential for contamination of the environment by herbicides. Where the potential for contamination is great, alternate pest control practices may be required.

III. RESIDUE USE AS FEED AND FUEL

Crop residues long have been an important source of feed for livestock and fuel for various purposes. The use of residues as feed and fuel undoubtedly will continue at current or greater rates because of its major economic importance to many producers.

Many crop producers often let their animals graze in fields after harvest of the crops for grain. Residues of crops such as wheat (*Triticum aestivum* L.) have limited nutrient value for animals. In contrast, residues of crops such as corn (*Zea mays* L.) and grain sorghum (*Sorghum bicolor* [L.] Moench) have greater nutrient value and can have a major impact on animal production. This is especially true if animals eat the grain that remains in the field. Harvested crop residues can be treated to improve their digestibility and nutrient value, but treatment is costly.¹⁹ Besides cost, another limitation to widespread treatment of crop residues to improve their quality as animal feed is the difficulty in handling the bulky materials. Where residues are used as feed, sufficient residues should be left in fields to provide adequate protection against erosion.

Crop residue use as fuel is common where other fuel sources are limited and costly, as in many developing countries. Residue use as fuel, however, has also been explored in developed countries, and satisfactory systems for such uses are available.²⁰ While handling and transportation of the bulky materials are not of major concern for small on-farm operations, they become major obstacles for large-scale operations. Residue removal for fuel also should be limited to ensure that adequate residues are left in the field to provide protection against erosion.

IV. MANAGEMENT TECHNIQUES TO MEET THE DEMAND FOR CROP RESIDUES

Because of the increasing emphasis on using crop residues for controlling soil erosion and the continued use of crop residues as feed and fuel, it appears certain that more residues will be used for these purposes and less will be incorporated into soil or even destroyed by burning. However, will there be enough to meet the demand? Certainly, in most humid regions where large amounts of residues are produced, it should be possible to meet the demand without major difficulty. However, in subhumid areas and especially in semiarid regions where residue production by dryland crops is inherently low, major competition for residues may occur. Where residue production is limited, one method of increasing the amounts of residues remaining on the surface would be to develop and use practices that inhibit residue decomposition, thus resulting in a residue carryover from crop to crop. This occurs to some extent where no-tillage cropping is practiced. Unger²¹ suggested some additional practices that could help meet the demand for crop residues. Most of the practices apply to any climatic region, but some are more adaptable to humid regions. Also, some are more adaptable to mechanized farming systems, whereas others are more adaptable to animal traction or hand labor conditions, as in developing countries.

A. Limited Residue Removal

The minimum amount of residue needed to control erosion on various types of soils can be determined. Residue in excess of this minimum amount could be removed for other purposes.

B. Selective Residue Removal

Parts of plant residues have greater value as feed, fuel, or other purposes than other parts. Hence, removing only that part needed for a given purpose would leave adequate amounts of residue on the land for conservation purposes.

Other types of selective residue removal include using only those residues that pass through the harvester as animal feed, allowing animals to forage on fields after harvest only while adequate residues remain, and removing little or no residue from highly erodible areas, but some or most residues from less-erodible areas.

C. Substitute High-Value Forages for Residues

Many crop residues have low nutritive value for animals. In contrast, forage crops harvested at the proper stage are much more nutritious. Growing such nutritious crops for feed would allow other crop residues to be managed for conservation purposes. Production of nutritious forages may result in increased animal production. Areas devoted to other crops would decrease and, hence, total production by those crops might be lowered initially. However, effective crop residue management, improved conservation of soil and water resources, and improved nutrient cycling could result in total yields comparable to those previously obtained from the entire land area. This, of course, would depend on the percentage of the area devoted to forage production.

D. Alley Cropping

Alley cropping is the practice of growing deep-rooted perennial shrubs or trees in rows far enough apart to permit crops to be grown between them. The shrubs or trees are pruned at the start of or periodically during the companion crop's growing season to reduce competition for light and water. The pruned leafy materials and twigs may be used as a mulch or as animal feed. Larger woody materials can be used as fuel. Perennials selected depend on the soil, climate, and crop to be grown. They should grow rapidly, fix nitrogen, have a multipurpose nature (mulch, feed, fuel), and be deep rooted to minimize competition for water and nutrients. Species of *Leucaena* and *Gliricidia* have performed well in alley cropping systems, especially in the more humid regions.

E. Utilization of Underused Land Areas

Many farms or villages have some land areas along fences, adjacent to streams or drainage ways, on rocky outcrops, on steep slopes, or in low-lying areas that are unsuitable for field crop production. Such areas sometimes are already used to grow plants for feed and fuel, but further development for such purposes would decrease the demand for residues as feed and fuel. Good management also could reduce the erosion that often occurs on such areas.

F. Improving the Balance between Feed Supplies and Animal Populations

A proper balance between feed supplies and animal populations should allow adequate residues to be maintained on the land for conservation purposes. However, when animal

populations are excessive, most residues may be removed from the land. Such overuse has resulted in serious soil deterioration, especially in countries where animals represent the owners' wealth. In such situations, agricultural, social, and economic factors must all be considered when implementing changes to obtain an improved balance between animal populations and feed supplies. National priorities and policy changes also may be needed to obtain the desired balance.

G. Use of Alternate Fuel Sources

Solar and wind energy units are widely used in some countries, but only to a limited extent or not at all in others. Increased use of such energy units must consider social, economic, and governmental factors, and technical advances may be required to develop practical units, especially for cooking purposes.

V. SUMMARY

Widespread emphasis is being placed on managing crop residues to control soil erosion by water and wind. Cropping systems designed to retain crop residues on the soil surface are termed conservation tillage systems. Major emphasis on development of such systems has occurred in the last 20 to 30 years, and suitable systems are available for many crops, soils, and climatic regions. For these systems, most crop residues are retained on the soil surface rather than incorporated by tillage, destroyed by burning, or removed for other purposes. Further technology advancements should help make conservation tillage adaptable to a wider range of conditions, thus enhancing the potential of this practice to conserve soil and water resources and to protect the environment.

Crop residues, however, often are used as feed and fuel, especially in developing countries. Also, residue production by nonirrigated crops usually is relatively low in subhumid and semiarid regions. Hence, the demand for residues often exceeds availability, and this problem undoubtedly will worsen in the future. Possible management practices to help meet the demand for residues include practicing limited and selective residue removal, substituting highly nutritious forages for residues used for animal feed, using alley cropping, utilizing underused land areas more effectively, improving the balance between feed supplies and animal populations, and using alternate energy sources such as solar and wind energy systems.

REFERENCES

1. Plowman, R. D., Bjerke, K. D., Jordan, J. P., Lee, J. E., Jr., Johnsrud, M. D., and Richards, W., Reasons for emphasis on crop residue management, paper prepared for Residue Management Workshop, Kansas City, MO, March 31 to April 2, 1992.
2. Harris, H., personal communication, 1990.
3. Conservation Technology Information Center, Tillage definitions, *Conserv. Impact*, 8(10), 7, 1990.
4. Kemper, W. D. and Schertz, D., Purpose of the workshop, paper presented at Residue Management Workshop, Kansas City, MO, March 31 to April 2, 1992.
5. Fryrear, D. W. and Bilbro J. D., Wind erosion control with residues and related practices, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 2.
6. Alberts, E. E. and Neibling, W. H., Influence of crop residues on water erosion, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 3.
7. Lindwall, C. W., Larney, F. J., Johnston, A. M., and Moyer, J. R., Crop residue management in conservation tillage systems, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 10.

8. Steiner, J. L., Crop residue effects on water conservation, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 4.
9. Horton, R., Kluitenberg, G. J., and Bristow, K. L., Surface crop residue effects on the soil surface energy balance, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 8.
10. Kladviko, E. J., Residue effects on soil physical properties, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 7.
11. Cochran, V. L., Sparrow, S. D., and Sparrow, E. B., Residue effects on soil micro- and macroorganisms, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 9.
12. Wicks, G. A., Burnside, O. C., and Felton, W. L., Weed control in conservation tillage systems, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 11.
13. Burton, R. L. and Burd, J. D., Effects of surface residues on insect dynamics, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 12.
14. Watkins, J. E. and Boosalis, M. G., Plant disease incidence as influenced by conservation tillage systems, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 13.
15. Hargrove, W. L., Schomberg, H. H., and Ford, P. B., Residue effects on nutrient cycling, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 6.
16. Putnam, A. R., Phytotoxicity of plant residues, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 14.
17. Harman, W. L., Economics of residue management in agricultural tillage systems, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 17.
18. Sims, G. K., Buhler, D. D., and Turco, R. F., Residue management impact on the environment, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 5.
19. Klopfenstein, T. J., Crop residue use as animal feed, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 15.
20. LePori, W. and Egg, R., Residue use as fuel, in *Managing Agricultural Residues*, Unger, P. W., Ed., Lewis Publishers, Boca Raton, FL, 1994, chap. 16.
21. Unger, P. W., Residue management for dryland farming, in *Challenges in Dryland Agriculture — A Global Perspective*, Proc. Int. Conf. on Dryland Farming, Unger, P. W., Sneed, T. V., Jordan, W. R., and Jensen, R., Eds., Texas Agricultural Experiment Station, College Station, 1988, 483.